



An Intelligent IoT-Based Rehabilitation System for Muscle Cramp Therapy in Army Personnel and Athletes

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Abstract: Muscle cramps are a prevalent issue among athletes and military personnel, often impairing performance and recovery. Traditional therapies lack real-time monitoring, personalization, and data-driven approaches. This paper presents an intelligent rehabilitation system that integrates sensor technology, IoT connectivity, and automated interventions for effective muscle cramp management. The system employs a NodeMCU microcontroller to interface with temperature sensors, an EMG sensor, a Peltier element, and an optional vibration motor. Real-time temperature regulation is achieved by monitoring knee temperature and activating the Peltier element upon detecting deviations. The EMG sensor enables continuous muscle activity tracking to identify cramp occurrences. Data is transmitted to a ThingSpeak cloud platform for remote monitoring and analysis via a user-friendly web application. The system's portability and adaptability make it suitable for field use. To assess the system's performance, we conducted tests involving around 20 participants. Experimental results demonstrate its efficacy in providing immediate relief and personalized therapy. This innovation addresses critical gaps in muscle cramp management, offering a scalable solution for high-performance individuals.

Keywords: Muscle cramps, IoT, real-time monitoring, EMG, Peltier element, rehabilitation system.

1. INTRODUCTION:

Muscle cramps represent a prevalent issue that affects diverse populations, particularly army personnel and athletes engaged in high intensity activities. These involuntary muscle contractions can lead to significant discomfort, impairing performance and hindering recovery. The etiology of muscle cramps is varied, stemming from factors such as dehydration, electrolyte imbalances, excessive physical exertion, and muscle fatigue. For active individuals in demanding environments, the implications of muscle cramps can be particularly severe, often resulting in interrupted training regimens, reduced performance levels, and a protracted recovery process. Traditional approaches to managing muscle cramps have primarily involved mechanical interventions, stretching techniques, and fluid replacements. However, these methods frequently lack the desired effectiveness, personalization, and sophistication required for contemporary athletic demands and military readiness. This gap in efficacy has underscored the necessity for pioneering therapeutic solutions that leverage advanced technologies, particularly those that facilitate real time monitoring and personalized responses to physiological signals.

As technology continues to penetrate the realm of health and rehabilitation, there exists an opportunity to harness the power of the Internet of Things (IoT), automation, and sophisticated sensor technologies in addressing common physiological challenges. The integration of these technologies into rehabilitation systems could facilitate a transition from

reactive management strategies to proactive, preventative measures. Embracing innovations in sensor technology allows for better monitoring of physiological parameters, enabling timely interventions that can preemptively address issues like muscle cramps.

In this context, the proposed rehabilitation system marks a paradigm shift where therapy is no longer a one-size-fits-all model but a personalized experience tailored to the individual's physiological responses.

Central to this innovation is the NodeMCU microcontroller, a versatile and robust platform capable of supporting a variety of sensors and actuators that facilitate the precise detection and management of muscle cramps. This microcontroller allows for realtime data collection and responsive actions based on the user's physiological metrics. The deployment of an array of temperature sensors, EMG sensors, and Peltier elements creates a holistic system designed to monitor critical biomarkers and adjust therapy in real time. The convergence of these technologies positions the proposed solution as an integral part of physical rehabilitation, allowing users to engage in their activities with reduced risk of cramping, while speeding up recovery when incidents occur.

2. RELATED WORK

The field of muscle cramp management has undergone remarkable transformation in recent years, moving beyond traditional stretching and massage techniques to embrace cutting-edge technologies. Researchers and engineers are now developing sophisticated solutions that blend wearable tech with real-time physiological monitoring, offering more proactive and personalized approaches to cramp relief.

One exciting development comes from Prasanna's team [1], who created a smart wearable that acts like an early warning system for cramps. Their device cleverly combines moisture and temperature sensors with a built-in heating pad, automatically delivering warmth when it detects cramp onset. Taking temperature therapy further, Sivamani and colleagues [2] designed a versatile massager that alternates between heating and cooling, enhanced with gentle vibrations to soothe tense muscles - imagine a portable spa treatment specifically for cramps.

Electromyography (EMG) technology has opened new frontiers in cramp detection. Researchers like Raju [3] have developed advanced EMG systems that can pinpoint writer's cramp with impressive accuracy, while Leeudomwong's team [4] adapted this technology to help dialysis patients who frequently suffer from painful muscle contractions. Beyond electrical signals, Yang's work [5] with ultrasound therapy shows how sound waves can actually relax muscle tension and prevent cramping - a surprising but effective approach.

The Internet of Things (IoT) revolution hasn't overlooked cramp management either. Thangam's group [6] created "smart shoes" that not only track athletic performance but can detect early signs of muscle cramps, alerting athletes before serious discomfort sets in. Meanwhile, Rahman's innovative soft robotics [7] offer a glimpse into the future - imagine wearable muscles that could actively prevent cramps before they start. For more complex movement disorders like dystonia, researchers are exploring even more advanced solutions. Murase's work [8] with magnetic brain stimulation and Hashimoto's brain-computer interfaces [9] represent groundbreaking approaches that could eventually benefit ordinary muscle cramp sufferers.

Together, these innovations mark a paradigm shift from reactive to proactive cramp management. No longer limited to temporary fixes, today's technologies offer continuous monitoring, personalized treatment, and even prevention - all packaged in increasingly

Portable and user-friendly formats. As these solutions evolve, they promise to significantly improve quality of life for athletes, medical patients, and anyone who experiences the sudden agony of muscle cramps.

3.METHODOLOGY:

3.1 SYSTEM ARCHITECTURE:

The proposed system is built around a NodeMCU microcontroller, which serves as the central processing unit. The system integrates two temperature sensors, EMG Sensor, a Peltier element, and an optional vibrator for enhanced therapy. The temperature sensors are placed on the affected knee and a reference body point to monitor temperature variations. The Peltier element provides automated temperature regulation, while the ThingSpeak IoT platform enables real-time data visualization and remote therapy customization.

3.2 SYSTEM DESIGN:

The architecture comprises:

1. **NodeMCU Microcontroller:** Acts as the central processing unit, interfacing with sensors and actuators.
2. **Temperature Sensors (DS18B20):** Placed on the knee and a reference body point to monitor thermal variations.
3. **Peltier Element:** Regulates knee temperature by heating or cooling based on sensor inputs.
4. **EMG Sensor (MyoWare):** Detects muscle activity to identify cramp occurrences.
5. **Button type Vibration Motor:** Provides optional muscle stimulation for enhanced relief.

3.3 PROPOSED SYSTEM:

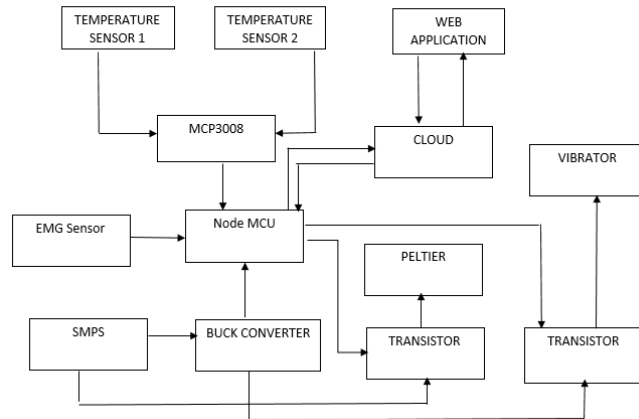


Fig .1. Block Diagram

The operational workflow of the proposed muscle cramp therapy system can be outlined in a structured format, detailing the processes from initial user setup to realtime intervention. The user begins by registering on the web application, where they input their physiological parameters and preferences regarding therapy modes.

Once activated, the system commences with a selfdiagnostic phase, during which it verifies the functionality of all hardware components. This phase is crucial in ensuring that subsequent data acquisition is reliable. The system continuously collects data from the temperature and EMG sensors, analyzing this in realtime.

If the algorithm identifies a muscle cramp, it will automatically initiate the appropriate therapeutic responses, modulating temperature or activating vibration based on preset user preferences. During this entire process, updates are transmitted to the cloud, allowing for remote monitoring of user data.

Lastly, the software allows users to view realtime data analytics on the web application, including insights on their muscle activity trends over time. This feedback not only encourages consistent engagement with the therapy system but also aids in modifying future interventions to further enhance therapeutic outcomes.

3.4 HARDWARE INTEGRATION:

1. Hardware Component Integration

Once the design was finalized, the hardware components were sourced and assembled. The integration process involved configuring the sensors and the Peltier element to work effectively under the control of the NodeMCU microcontroller. A prototyping board facilitated initial connections between sensors and the microcontroller to ensure effective communication and feedback mechanisms.

The temperature sensors were calibrated to optimize the accuracy of temperature readings. Similarly, the EMG sensors required precise placement for accurate detection of muscle activity. Initial tests verified that data from these sensors could be processed by the microcontroller in realtime.

Each actuator, including the Peltier element and vibrator, was programmed to respond based on sensor inputs. The control algorithms developed for these actuators ensure swift and appropriate responses to the physiological data being monitored. A dedicated power supply was also developed to maintain the entire system's portability, emphasizing the importance of delivering a lightweight and easily transportable device..

3.5 SOFTWARE DEVELOPMENT:

Following hardware assembly, the software components were developed concurrently. The software aspect concentrated on programming the microcontroller, utilizing languages such as C++ for device level programming and JavaScript for web interface development. The primary functions included data acquisition from sensors, signal processing, and decision making algorithms to control the actuators.

The system implemented real time data acquisition algorithms to collect muscle activity and temperature variations continuously. Sensor data was routed through the microcontroller, where it was processed and compared against predefined thresholds. When abnormal values were detected, the control algorithms triggered responses such as temperature modulation through the Peltier element or vibration patterns to provide muscle stimulation.

Additionally, software development extended to creating the ThingSpeakbased cloud platform. This platform served as an interface for data visualization, allowing users to monitor their physiological data remotely. The web application was developed with user experience in mind, ensuring that it conveyed necessary information effectively and allowed for easy customization of therapy modes.

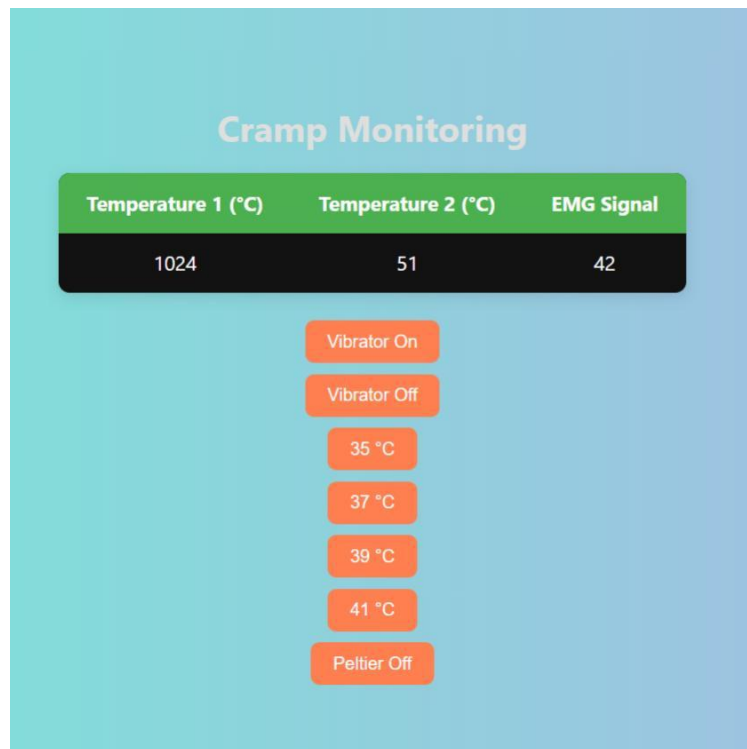


Fig. 2. App for Muscle cramp detection and solution provider system.

3.6 ALGORITHM DEVELOPMENT:

The core algorithm driving the system focuses on physiological data analysis and adaptive intervention. It operates in multiple phases, beginning with data collection. Sensors continuously monitor muscle activity and temperature, sending this information to the microcontroller. Once the data is acquired, it undergoes preprocessing to filter out noise and irrelevant information. This phase is critical in ensuring that the subsequent analysis of muscle activity is based on accurate readings. Utilizing threshold based detection, the algorithm identifies significant deviations in muscle activity consistent with cramping episodes. Upon detecting a cramp, the algorithm initiates an immediate response from the actuators. If the temperature of the knee is found to be outside the predefined therapeutic range, the Peltier element is activated, ensuring rapid temperature adjustment. In tandem, the optional vibrator is triggered based on user preferences set within the web interface.

4. EXPERIMENTAL SETUP AND RESULTS:

The system was tested with the group of 20 individuals. The groups include the individuals around the age of 19 to 25 including sports persons.

The temperature readings are taken two regions, one for reference which is taken from the upper limb and the other reading is taken below the knee specifically in the Gastrocnemius and Soleus muscles region which are prone to muscle cramp. The EMG readings are also taken in the same region.

The normal temperature range is around 36°C to 37°C. The temperature around the region of muscle cramp may increase upto 40°C. The EMG reading for normal individual is around 16 to 20. The EMG reading above or below the normal range indicates the muscle cramp in that region.

Patient ID No.	Temperature 1 (°C)	Temperature 2 (°C)	EMG Reading	Results
1	36.7	36.2	15.6	Normal
2	37.2	37.8	20.3	Normal
3	37.6	37.4	15	Normal
4	37.7	37.4	20.6	Normal
5	36.7	37.6	16.5	Normal
6	36.5	36.1	19.2	Normal
7	37.7	37.9	20.3	Normal
8	36.2	37.8	20.7	Normal
9	36.1	36.3	18.3	Normal
10	36.7	36.6	17.2	Normal
11	37.1	44	24	Cramp
12	36.5	37.2	18.3	Normal
13	36.7	43.8	24	Cramp
14	37.4	38	19.4	Normal
15	37.7	37.9	17	Normal
16	36.5	37.8	20.5	Normal
17	36.3	36.4	19.5	Normal
18	37.9	36.5	15.7	Normal
19	36.4	36.2	19.1	Normal
20	36.7	37.1	19.8	Normal

Table 1 : Quantitative results of temperature sensor and EMG measurement

The results shows We had checked 20 individuals and all the people temperature reading and EMG value is noted and monitored in our device.

NUMERICAL OUTPUT:



Fig. 3. Normal person Output.



Fig.4. Cramp person Output

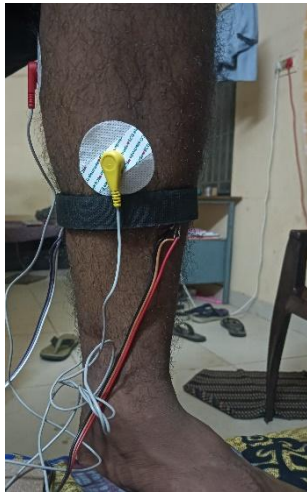


Fig. 5. Prototype setup

2. CONCLUSION:

We had checked 20 individuals and all the people temperature reading and EMG value is noted and monitored in our device. The proposed intelligent muscle cramp therapy system leverages advanced sensor technologies and IoT capabilities to address a critical necessity faced by army personnel and athletes alike. By combining real time physiological monitoring with automated intervention strategies, it endeavors to provide personalized and effective muscle cramp management. This multitiered approach not only enhances recovery times but also mitigates the risk of future cramp occurrences, thereby promoting improved overall performance.

The integration of a user friendly web application and a robust cloud platform ensures that users can remotely monitor their therapy and adjust parameters as necessary, leading to a more tailored therapeutic experience. Furthermore, by employing security measures and prioritizing user privacy, the system fosters trust and reliability among its users.

Overall, this innovative solution marks a significant step in the field of rehabilitation technology, presenting an effective solution to a pervasive issue while paving the way for future advancements in personalized healthcare.

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